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printed From The Journal Of
The Royal Astronomical
Society Of Canada,
May-June, 1912

ORBIT OF ε PERSEI FROM THE H AND K LINES

BY

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By J. B. Cannon

ξ PERSEI is one of those stars in which the velocities given by the H and K lines of calcium differ greatly from those from the broad lines of hydrogen and helium. The spectrum is placed by Miss [illegible] in the Oe 5 B class. The lines showing are those of h[illegible] helium and calcium. A few iron lines appear, but not [illegible] sufficient frequency to make them useful for measurement. The hydrogen and helium lines are very broad and ill-defined, the latter lines especially being very poor. The calcium lines are fairly good, sometimes both being easily measurable, sometimes only one and in some cases neither appears sufficiently defined to make measurement possible.

The first published measures of this star appeared in *Astrophysical Journal*, Vol. XVIII., p. 383, 1903, five measures being given of the broad lines in an article by Professor Frost under the heading — "An Orion Star of Great Radial Velocity." The range — 9 kilometres — was not considered sufficient ground to pronounce it a binary. Later in *Astrophysical Journal*, Vol. XXIX., p. 236, 1909, Professor Frost announced another measure of this star giving a range of 30 kilometres. In that note he remarked that the H and K lines have a moderate positive velocity with a range of about 25 kilometres, these lines differing greatly in the velocities shown from the values derived from the broad lines.

Observations on the star were first made here in 1908, a few plates being taken. It was then dropped from the observing list until 1910, and plates were taken in the seasons of 1910-11 and 1911-12. Although the broad lines were measured at first, — where measurement was possible, — as well as H and K, it was not felt that these diffuse lines would be of any aid in ascertaining anything in regard to the orbit of the star, and attention was given almost exclusively to the H and K lines of calcium. These lines were not always found on the plates, but generally one or other of them was well enough defined to be measured. Of the 1908 plates only two gave measures of K which were considered reliable. Of the later plates — 1910-11-12, 41 plates were good enough to be useful in the determination of the orbit. The later plates were all Seed 23 and were much better than the earlier ones of Seed 27, although the fine-grained plate did not serve to make the broad lines measurable. As stated above, these broad lines were measured at first. An attempt was also made to get measures on the members of the second series of hydrogen with a view to determining the wave-lengths of these lines in this star, but the utter impossibility of anything definite in this regard led to the abandonment of the attempt.

The wave-lengths used for H and K were 3968·625 and 3933·825 respectively. K was, with very few exceptions, stronger than H. Some plates were found in which H and K gave widely different results. In such a case, if the lines were equally good, the plate was left out of consideration : if one was much better than the other that line was used.

Great aid was given in the work by the use of Yerkes measures of ten plates kindly sent me by Professor Frost, and of nine more plates loaned by Professor Frost and measured by me. As a check on the measures of a plate — here and at Yerkes,— two plates — I B 141 and I B 402,— were measured at both places. On one of these, I B 402, the measures were practically the same, but on the other — not too well-defined — a difference of ten kilometres was found. Of the nine plates taken at Yerkes and measured here, unfortunately four of them gave H and K differing considerably, while one of them gave only H measurable. Otherwise the Yerkes plates fit the accepted curve as well as can be expected from a spectrum which gives only one and at most two lines on which to base results.

Table I. gives Ottawa Observations ; Table II. Yerkes Observations.

TABLE I.—OTTAWA OBSERVATIONS

Plate	Julian Day	Phase	Vel.	Wt.	Lines	Residual	Remarks
1974	2,418,266·83	4·620	+ 18·0	½	K	− 4·7	
1999	280·72	4·613	+ 26·0	¼	K	+ 3·4	
3740	957·83	0·522	+ 10·3	1½	H & K	− 0·3	
3765	964·81	0·552	+ 4·9	½	K	− 5·4	
3777	970·91	6·653	+ 16·0	1½	H & K	− 0·3	
3817	9,011·61	5·653	+ 36·0	¾	H & K	+ 13·8	
3861	018·68	5·763	+ 22·0	1¼	H & K	+ 0·2	
3881	022·79	2·922	+ 14·2	½	K	+ 1·0	
3915	042·54	1·822	+ 7·5	1¼	H & K	− 0·4	
3921	046·54	5·823	+ 36·0	1	K	+ 14·4	
3929	049·55	1·882	+ 2·7	½	K	− 5·5	
3936	053·58	5·913	+ 24·7	¾	K	+ 3·6	
3957	055·57	0·952	+ 6·3	½	K	− 2·2	
3962	056·58	1·962	+ 3·6	1¼	H & K	− 4·9	
3974	067·66	6·083	+ 16·2	½	H & K	− 4·1	
3991	079·56	4·083	+ 13·3	1	K	− 7·0	
4020	091·58	2·202	+ 15·0	1	K	+ 5·8	
4056	102·50	6·173	+ 16·5	½	K	− 3·2	
4067	103·52	0·242	+ 5·4	½	K	− 6·9	
4552	293·89	2·932	+ 4·3	¼	K	− 8·9	
4634	322·77	4·113	+ 17·4	1	K	− 3·3	
4645	323·81	5·053	+ 30·5	½	H & K	+ 7·2	
4676	343·66	4·053	+ 25·1	1	H & K	+ 4·8	
4685	344·74	5·133	+ 15·8	½	K	− 7·4	
4690	351·71	5·143	+ 16·8	1	K	− 6·4	
4715	377·59	4·303	+ 30·8	¼	K	+ 9·3	
4729	390·60	2·332	+ 5·4	¾	K	− 4·4	
4738	396·70	1·482	+ 15·5	1	H & K	+ 7·9	
4745	403·58	1·402	+ 11·0	¼	K	+ 3·3	
4758 4759	412·50	3·372	+ 16·8	¾	H & K K	+ 0·8	
4779	414·60	5·473	+ 18·5	1	K	− 3·7	
4801	421·62	5·543	+ 21·0	1½	K	− 1·6	
4819	428·56	5·533	+ 15·0	1	K	− 7·6	
4828	434·51	4·533	+ 21·8	1¼	H & K	− 0·5	
4831	443·52	6·593	+ 21·2	¼	K	+ 4·4	
4833	445·55	1·672	+ 11·9	¾	H & K	+ 4·2	
4839	446·53	2·652	+ 7·3	1	H & K	− 4·2	
4843	447·53	3·653	+ 21·6	1¼	H & K	+ 3·6	
4849	453·56	2·732	+ 14·0	1¼	H & K	+ 2·0	
4853	456·58	5·753	+ 17·8	1	K	− 4·0	
4858	461·54	3·763	+ 21·6	¾	H & K	+ 2·9	
4869	467·55	2·822	+ 14·2	½	K	+ 1·7	
4874	468·55	3·813	+ 15·6	½	K	− 3·2	

TABLE II.—ξ PERSEI, YERKES PLATES

MEASURED AT YERKES

Plate	Julian Day	Phase	Vel.	Wt.	Lines	Residual	Remarks
I B							
101	2,416,384·86	6·371	+ 23			+ 4·5	
119	404·81	5·468	+ 29			+ 6·2	
141	411·78	5·487	+ 6			- 16·6	Cannon's measure +
179	426·79	6·595	+ 1c			- 6·7	{16·0 Residual 6·6.
203	450·60	2·661	+ 23			+ 11·4	
232	476·50	0·697	- 10			+ 0·5	
304	586·60	6·532	+ 24			+ 6·7	
402	754·93	1·087	+ 2			- 6·1	
465	845·5[illegible]	1·354	+ 12			+ 4·3	
821	7,433·8[illegible]	5·800	+ [illegible]			+ 1·5	

MEASURED [illegible] CANNON

Plate	Julian Day	Phase	Vel.	Wt.	[illegible]	Residual	Remarks
I B							
850	2,417,468·90	6·055	+ 14·5	½	[illegible]	- 0·0	
879	496·84	6·201	+ 4·5	½	[illegible]	- 15·0	
935	580·56	6·499	+ 19·3	¾	H [illegible]	+ [illegible]	
1199	860·81	1·758	- 0·5	½	K	- 8·3	H & K differ
1208	867·73	1·747	- 5·9	½	K	13·7	H & K differ
1216	869·76	3·757	+ 13·7	1½	H & K	4·8	
1260	910·68	2·971	+ 3·4	½	H	[illegible]	H only
1289	926·58	4·969	+ 7·9	1	K	[illegible]	H is highly [illegible] ve
1350	961·51	5·144	+ 18·6	1	K		[illegible] is much more [illegible] ve

The period finally decided on after a gre[illegible] was 6·951 days. There are some fairly large res[illegible] the probable error of an average plate is ± 3·6, a[illegible] satisfactory when one considers that many value[illegible] on one line which is not always very well defin[illegible]

The observations were grouped into el[illegible] normals which appear in Table III. (The phases are from [illegible] T).

TABLE III.

No.	Julian Day	Phase	Vel.	Wt.	Residual
1	2,419,342·88	3·893	+ 19·42	3	+ 0·19
2	2,419,040·51	4·550	+ 22·42	1	+ 0·19
3	347·99	5·123	+ 19·98	1	– 3·22
4	349·25	5·543	+ 21·65	2	– 0·98
5	141·60	5·803	+ 24·96	2	+ 3·26
6	082·24	6·433	+ 17·36	1·5	– 0·62
7	8,988·36	0·472	+ 8·24	1	– 2·57
8	9,300·21	1·322	+ 12·23	1	+ 4·65
9	128·76	1·852	+ 6·44	2	– 1·48
10	302·20	2·412	+ 9·56	1·5	– 0·44
11	367·68	2·942	+ 13·95	1·5	+ 0·85

Preliminary elements for the orbit follow :—

$$\text{Period} = 6{\cdot}9[illegible] \text{ days}$$
$$e = {\cdot}1$$
$$\omega = 150^\circ$$
$$K = 7{\cdot}75 \text{ km.}$$
$$T = 2{,}418{,}249{\cdot}349 \text{ J. D.}$$
$$\gamma = +\ 15{\cdot}92 \text{ km.}$$

Observation equations were formed and normal equations from them, and a solution put through with the object of getting a closer approximation to the true orbit. This resulted in corrections to the elements as follows :—

$$\delta\gamma = -\ {\cdot}52$$
$$\delta K = \pm\ {\cdot}00$$
$$\delta e = -\ {\cdot}11$$
$$\delta\omega = -22^\circ{\cdot}47$$
$$\delta T = -\ {\cdot}496 \text{ days.}$$

There is one peculiarity about these corrections, δe has the value – ·11 whereas the preliminary value is only ·1. This would seem to indicate that the orbit is circular and ω indeterminate. This will be further seen from the oscillations in the value of ω in the following operations. New preliminary values were taken in which

$e = {·}05$
$\omega = 60°$
$K = 7{·}75$ km.
$T = 2{,}418{,}247{·}607$ J. D.
$\gamma = 15{·}06$ km.

It might be stated here that the value of $\Sigma\, pvv$ was reduced by the solution, the corrected e being taken as zero, from 74·7 to 73·2. With the new preliminaries the value was 72·5. It was apparent that any solution would fail to make much reduction in the value of $\Sigma\, pvv$ the signs being well distributed in the residuals. However a least-squares solution was made with the new preliminary values. The resulting corrections were as follows :—

$\delta\gamma = +\ {·}34$ km.
$\delta K = +\ {·}12$ km.
$\delta e = +\ {·}022$.
$\delta\omega = +\ 81°{·}80$
$\delta T = +\ 1{·}511$ days.

whence we obtain the new values —

$\gamma = 15{·}40$ km.
$K = 7{·}87$ km.
$e = {·}072$
$\omega = 141°{·}80$
$T = 2{,}418{,}249{·}118$ J. D.

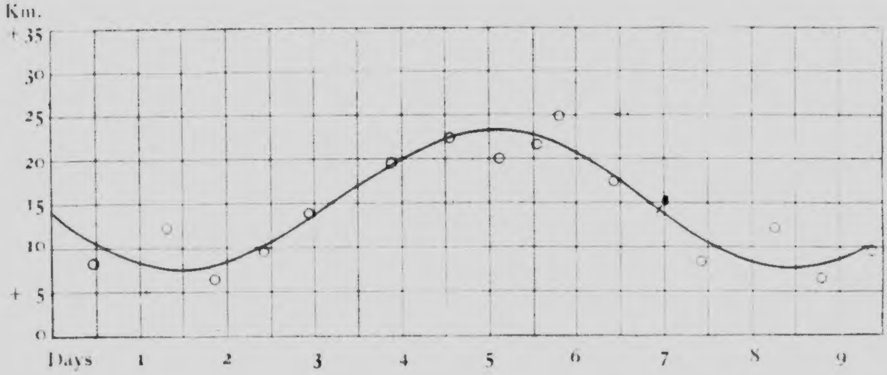
It is rather strange that e and ω should have come back to so nearly the original value. $\Sigma\, pvv$ was reduced from 72·5 to 69·5. The agreement between computed and observation equation residuals was bad and a third solution was made for the sake of completion. The corrections found were :

$\delta\gamma = \pm\ {·}00$ km.
$\delta K = \pm\ {·}00$ km.
$\delta e = -\ {·}038$
$\delta\omega = -\ 42°{·}62$
$\delta T = -\ {·}810$ days,

and hence the final elements—

P = 6·951 days.
K = 7·87 km.
γ = 15·40 km.
e = ·034
ω = 99°·18
T = 2,418,248·308

A summary follows showing results of the various solutions made in the determination. The probable errors of the elements are added in the last column.



VELOCITY CURVE OF ξ PERSEI

SUMMARY

	Element	Preliminary	After 1st Solution	New Preliminary	After 2nd Solution	After 3rd Solution
P	Period	6·951 days	6·951 days	6·951 days	6·951 days	6·951 days
K	Half-Amplitude	7·75 km.	7·75 km.	7·75 km.	7·87 km.	7·87 km. ± 0·80
γ	Vel. of system	15·92 km.	15·40 km.	15·06 km.	15·40 km.	15·40 km. ± 0·60
e	Eccentricity	·1	− ·01	·05	·072	·034 ± ·114
ω	Angular distance of Periastron from ascending node	150°	127°·53	60°	141°·80	99°·18 ± 15°·49
T	Time of Periastron passage	2,418,249·349 J. D.	.... 248·853	.... 247·607	.... 249·118	.... 249·308 ± 1·575
$a \sin i$	½ Major axis × sine of inclin.					751,800 km.
	Prob. Error of Nor. Place, Wt. Unity					± 2·3 km.
	$\Sigma\, pvv$	74·7	73·2	72·2	69·5	68·2

After the completion of the orbit-determination from the calcium lines, the results from the broad lines were reviewed. The diffuseness of the lines, however, and consequent uncertainty of the measures from them made it quite impossible to secure any reliable information from them. Some information in regard to these lines would have been very interesting, but it seems that so far we must be content with the one fact which seems assured — the broad lines show a much higher positive velocity than the H and K lines.

In conclusion I wish to thank Dr. King for the interest he has shown during the progress of this work.

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June, 1912